Operation of CHP Systems at UMD, Measurement, Data Evaluation and Technology Transfer

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Overview

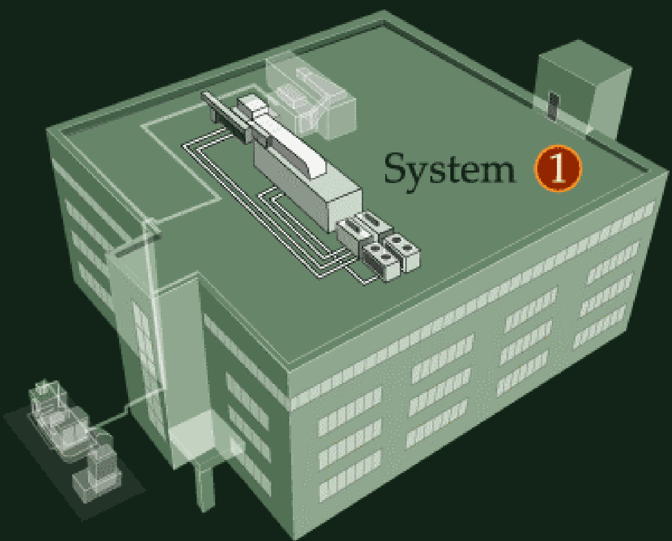
- Introduction
- Objectives
- Project Team/Partnerships
- Operation
- CHP Know-How/Accomplishments
- Future work
- Summary

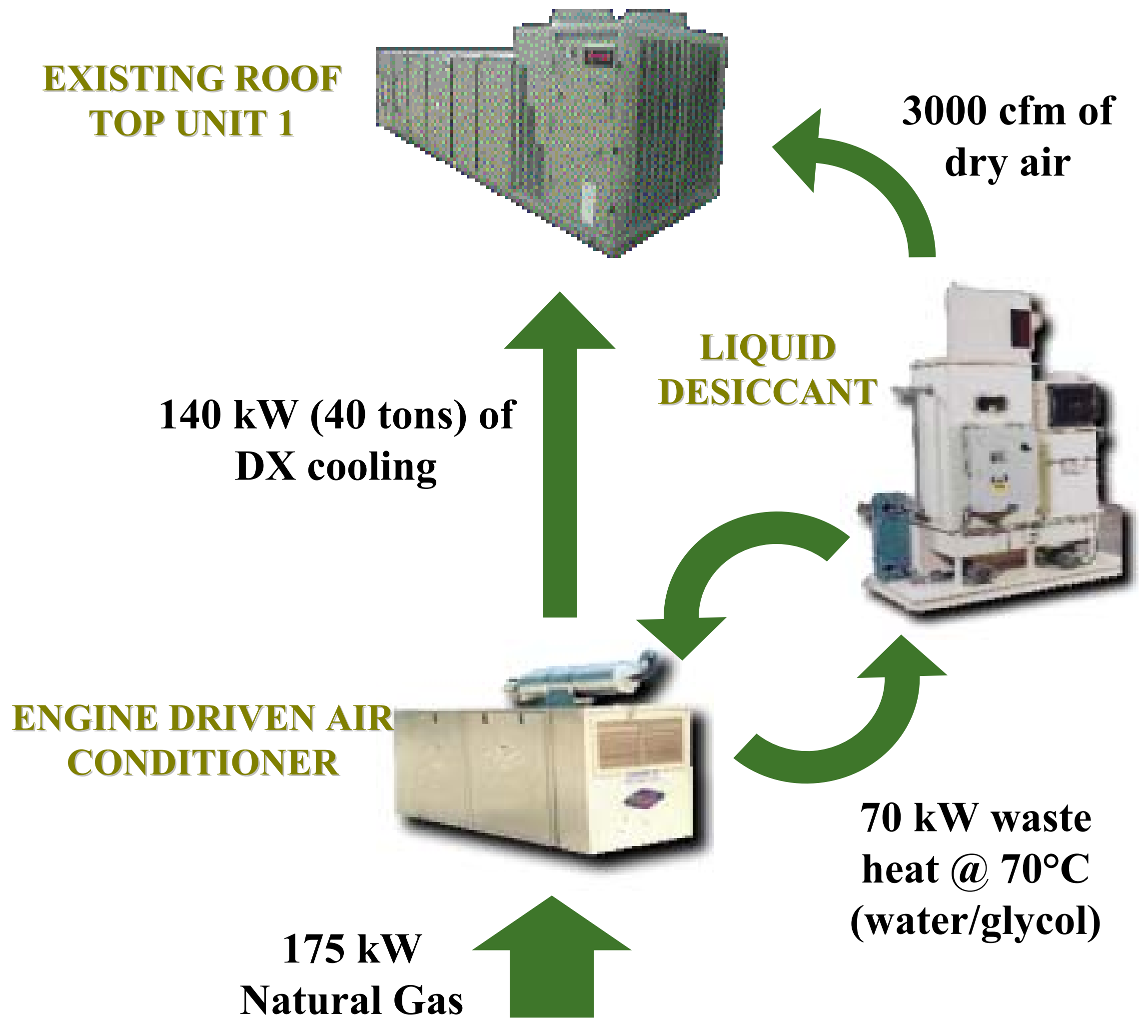
Introduction – Chesapeake Building

- Medium sized office building on UMD campus, 51,000 ft^2
- Represents 23% of U.S. office space
- CHP systems installed late 2000
- 2 completely separate air conditioned zones within building
- CHP systems only operate in the cooling season as heating is distributed electric reheat
- Both systems have sensible and latent cooling components

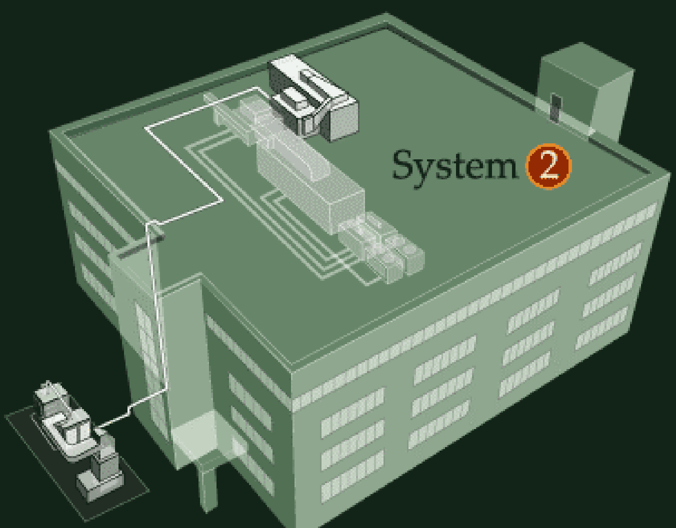
The Chesapeake Building at UMD

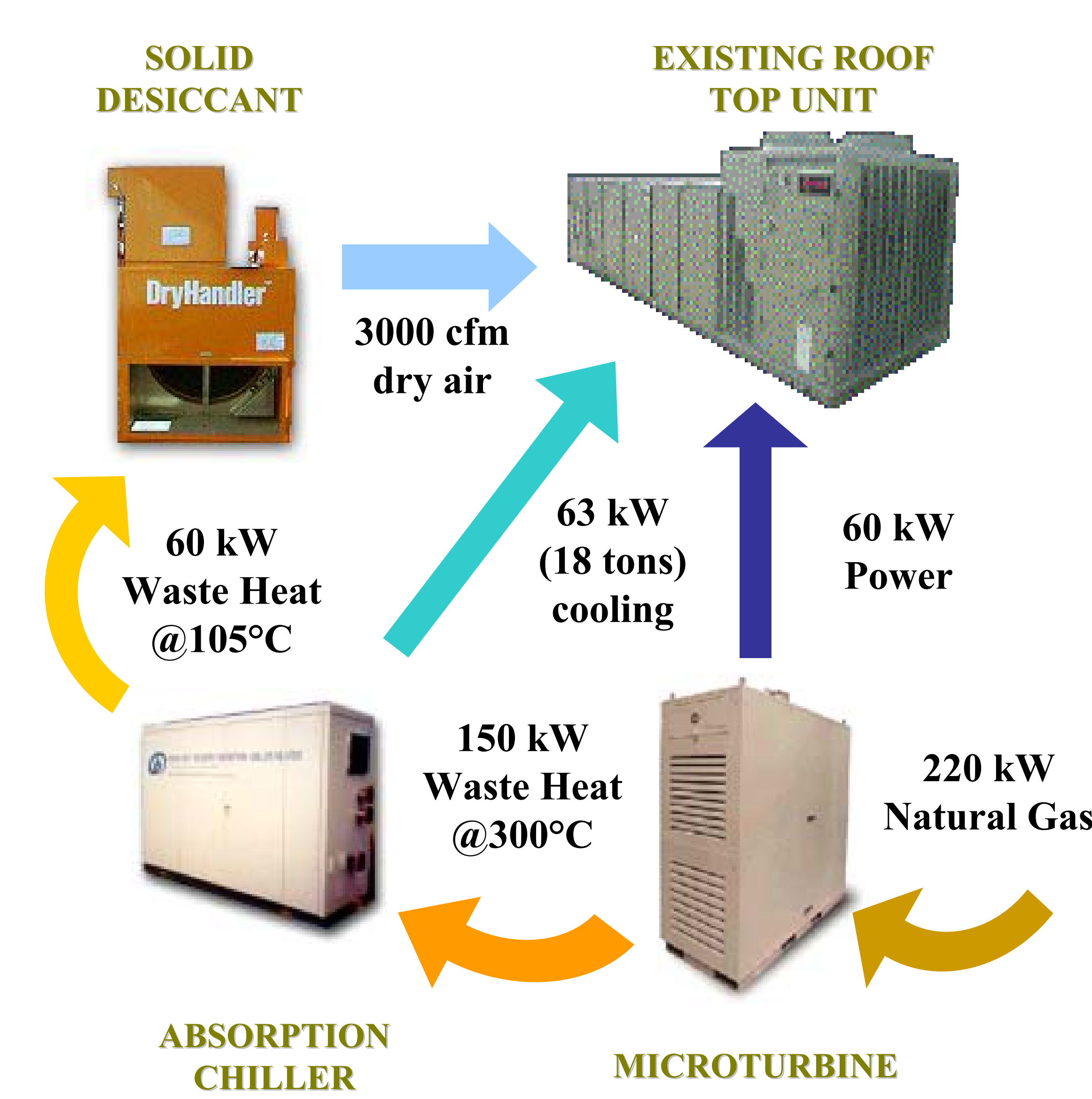
Introduction
- CHP System 1





Introduction - CHP System 2





CHP Research Objectives

- Benchmark CHP equipment performance
- Benchmark integrated equipment system performance in an occupied building
- Develop and verify computer models
- Identify component and system improvements for current packaged CHP manufacturers, “next generation” products and fuels
- Technology Transfer

CHP System 2 at the Chesapeake Building

CEEE Organization

- **R. Radermacher**
  Director
  - **Advisory Board**
  - **CEEEBase**
  - **Advanced Heat Exchangers**
  - **System Optimization, HX, Compr/Exp. Design**
  - **Refrigerant Alternatives**
  - **CHP, Sorption Systems**

CEEE Consortium Partners

1	Baltimore Aircoil	6	DOE/ORNL	12	Thermoflow
2	Broad	7	Heatcraft	13	Trane
3	Capstone	8	Honeywell	14	Tridium
4	Daikin	9	Kathabar	15	Trigen
5	DTE Energy	10	PEPCO	16	Trion
		11	Propane Res. Council	17	Sanyo

Trigen Contribution and Fellowships

TRIGEN

Capstone

CEEE
Center for Environmental Energy Engineering

EPRI

pepco

United States Environmental Protection Agency

CAPRON

STULZ

BROAD AIR CONDITIONING
远大空调有限公司

DAIKIN

TRIDIUM

B.A.C.

Honeywell

Department of Energy United States of America

ornl
OAK RIDGE NATIONAL LABORATORY

Pacific Northwest National Laboratory

PROPANE
EXCEPTIONAL ENERGY

KATHABAR®

SANYO

TRION®

Operation - sensor calibration

- 180 sensors throughout building
- Temperature, humidity and flow rate sensors calibrated
- Data collected and statistically sampled for calibration in HP VEE software
- DAS automatically records all test points once/minute.

DAS sensor board collects data continuously to monitor building performance

Operation - Weekly Test Schedule

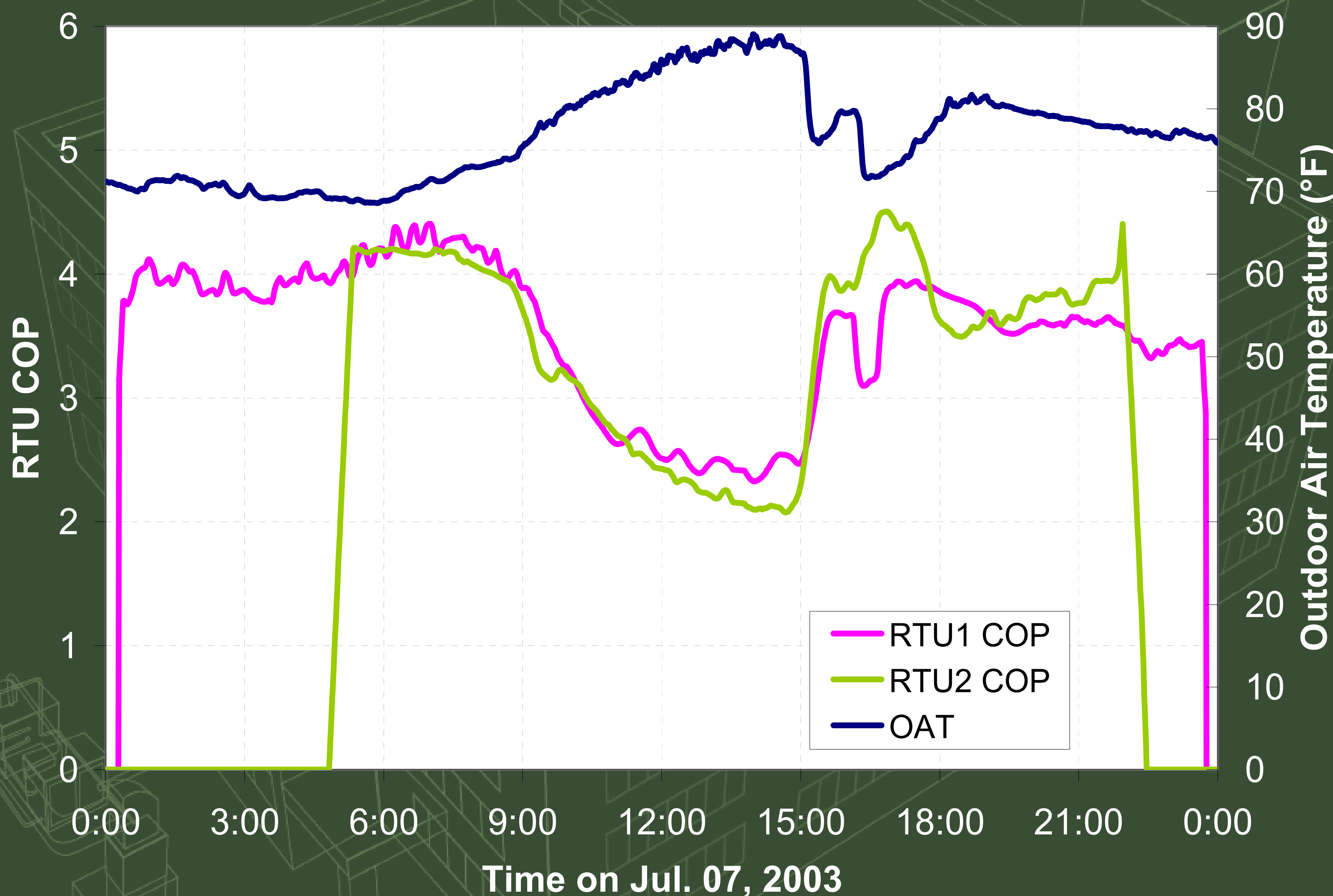
Weekday	Test Item	Changeable Variables	Fixed Variables	Purpose
Monday	Baseline: run MT at 10-60kWe power output and run chiller and ATS together	MT power (10kW-60 kW)	Chiller at default settings ATS burner is off	Set CHP baseline
Tuesday	ATS Integration test: ATS runs on the exhaust and burner	Burner temperature	MT=60kWe, Chiller at default settings	Make up heat for ATS
Wednesday	Air cooled simulation tests	Condenser return temp up to 120°F	MT=60kWe, Chiller at default settings	Air cooled similarity tests
Thursday	Broad Integration test: with ATS off	Cooling water temp. (~105°F) Chilled water temp.(~45°F) Exhaust temp. (~550°F)	MT=60kWe	Investigate back pressure effect
	ATS on burner alone	ATS on/off		ATS baseline and transient test to investigate the impact on RTU2
Friday	Broad Integration test: with ATS on	Cooling water temp. (~105°F) Chilled water temp.(~45°F) Exhaust temp. (~550°F) Cooling load (adjust the valve)	MT=60kWe, ATS on exhaust	In CHP mode, investigate the effect of several variables

Operation - Test

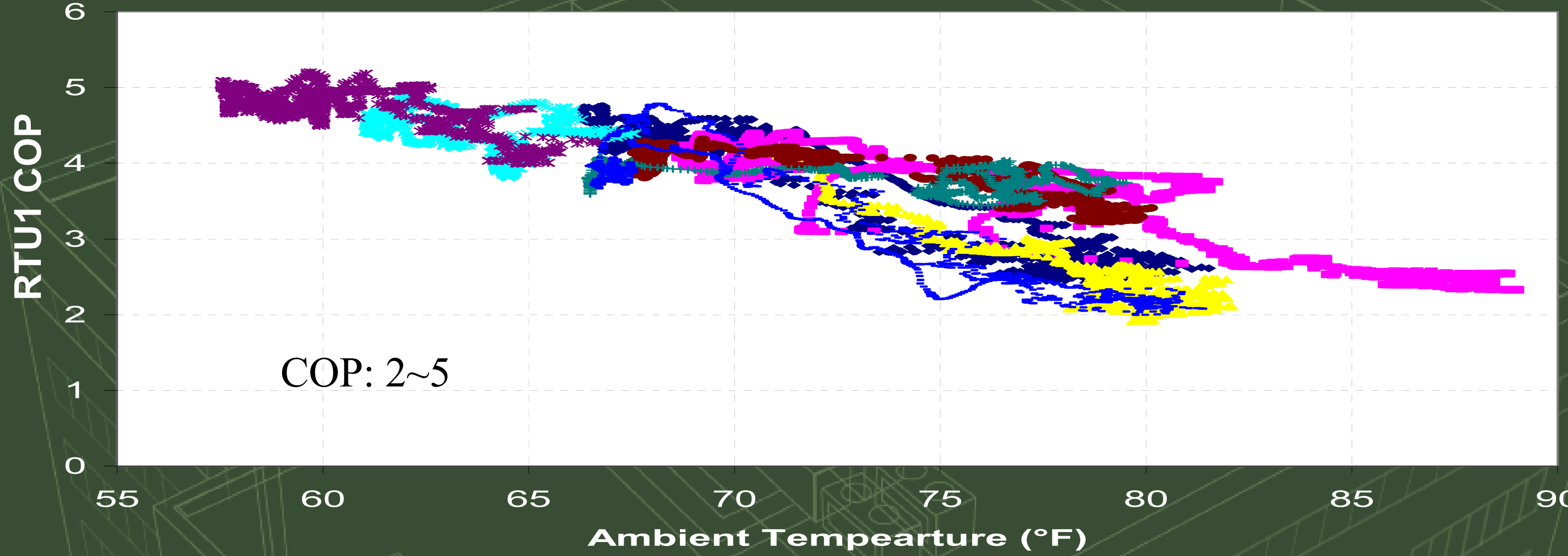
- Set weekly test schedule
  - To make use of different weather conditions and compensate the deficiency of real building tests.
  - To compare different CHP operation in 2 similar days.
- Recorded comprehensive test log.
- Ran CHP System 2 on natural gas for 450 hrs (equal to 35 hrs/week) in Jun. ~ Aug. 2003
- Ran microturbine on propane since fall, 8 hrs/day
- Enthalpy wheels comparison test

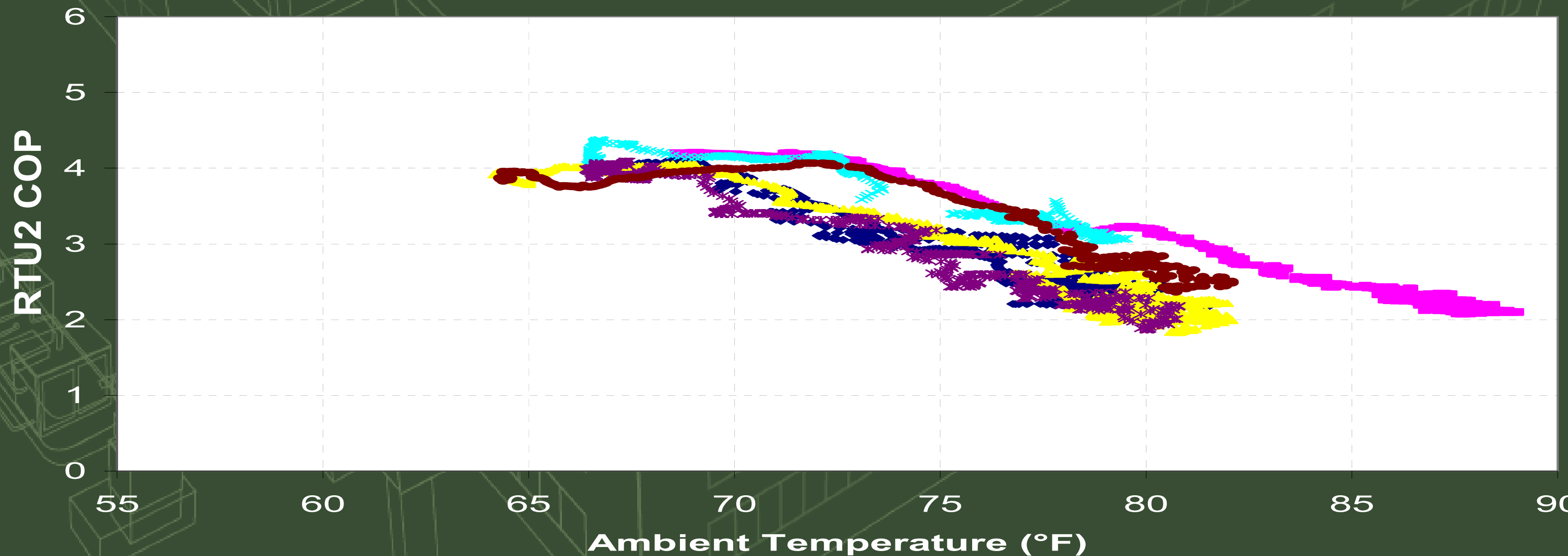
Propane tank outside the Chesapeake building

Roof Top Unit – Electric Vapor Compression

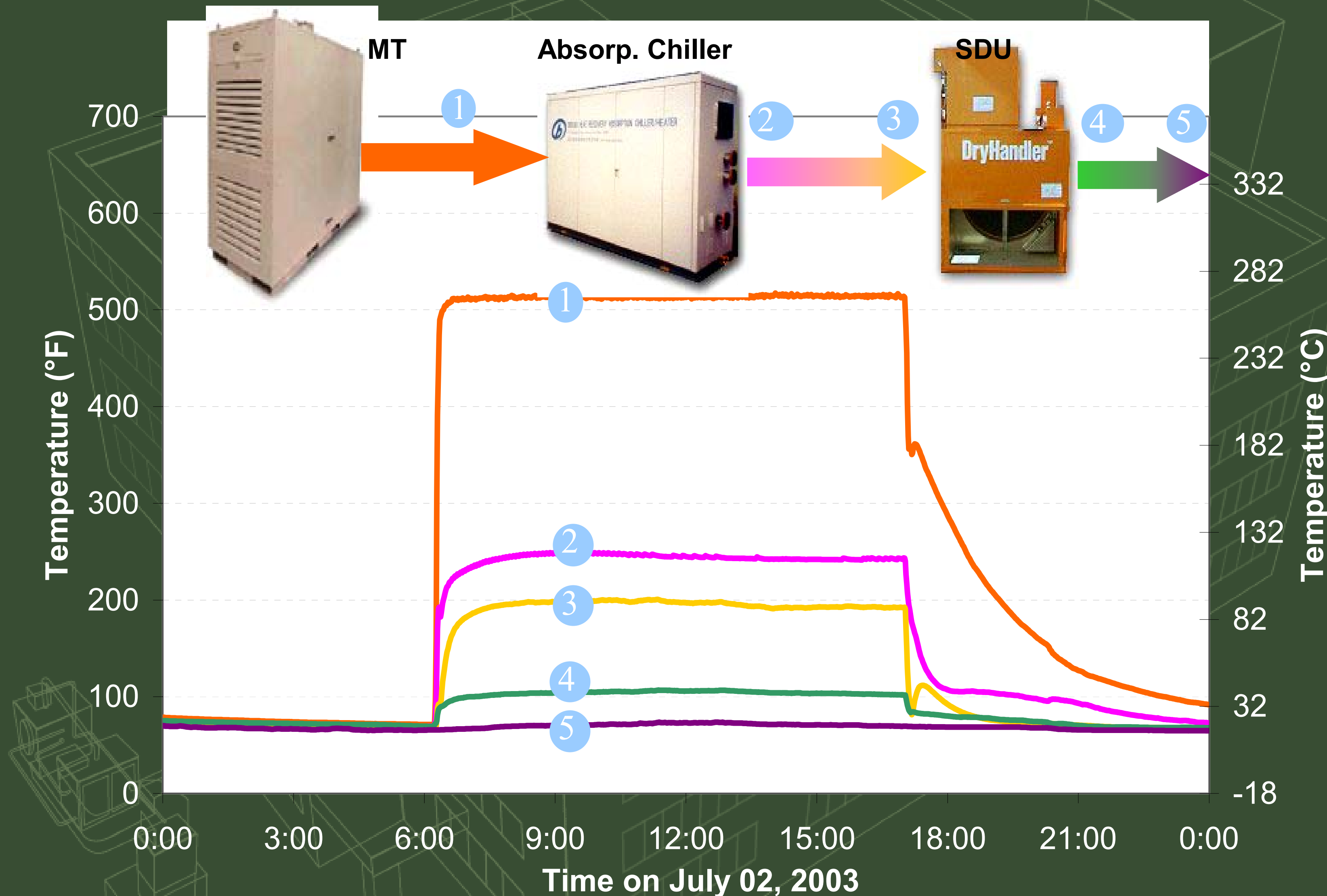


COP of Roof Top Unit

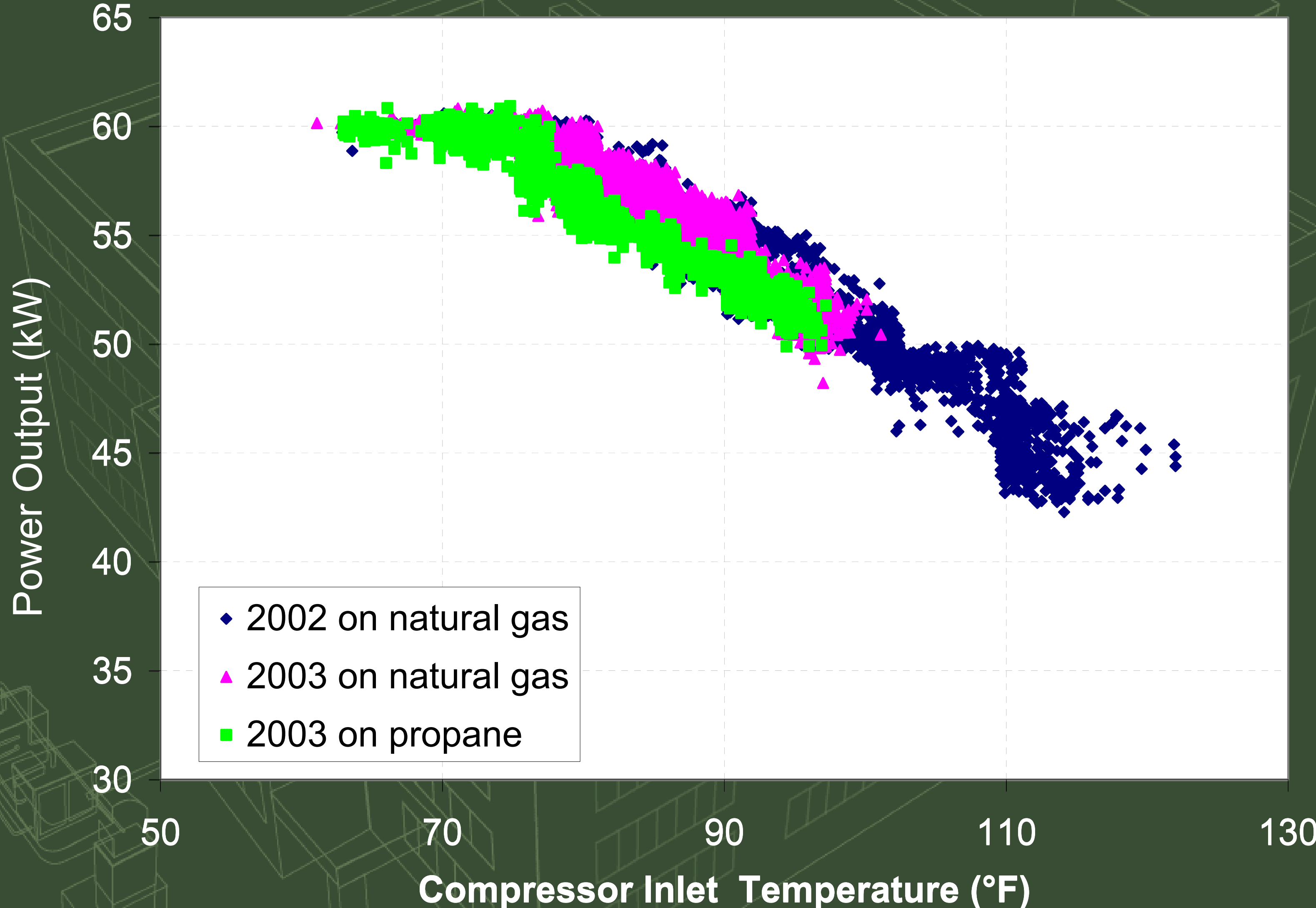




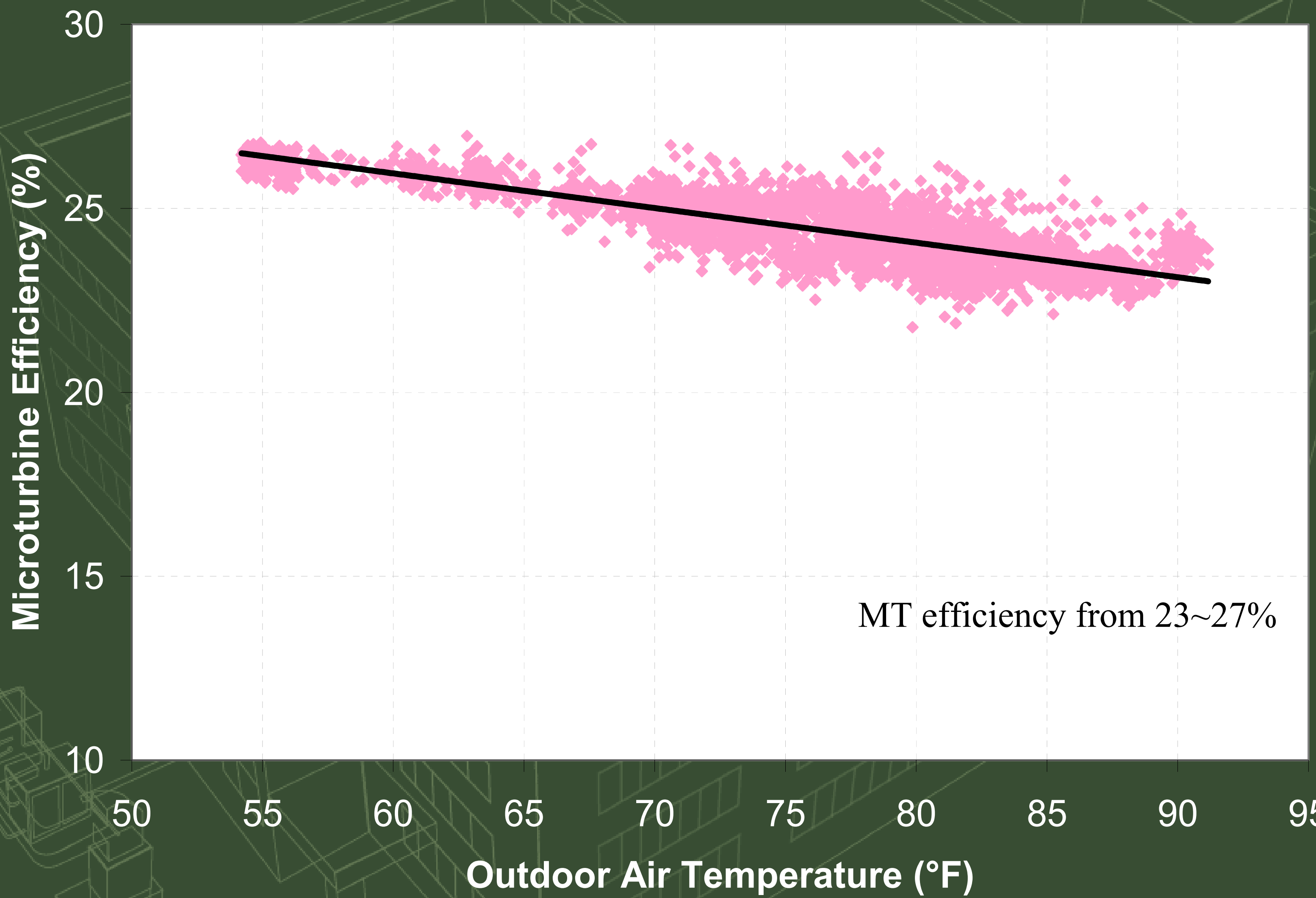
Temperature Profile of CHP System 2



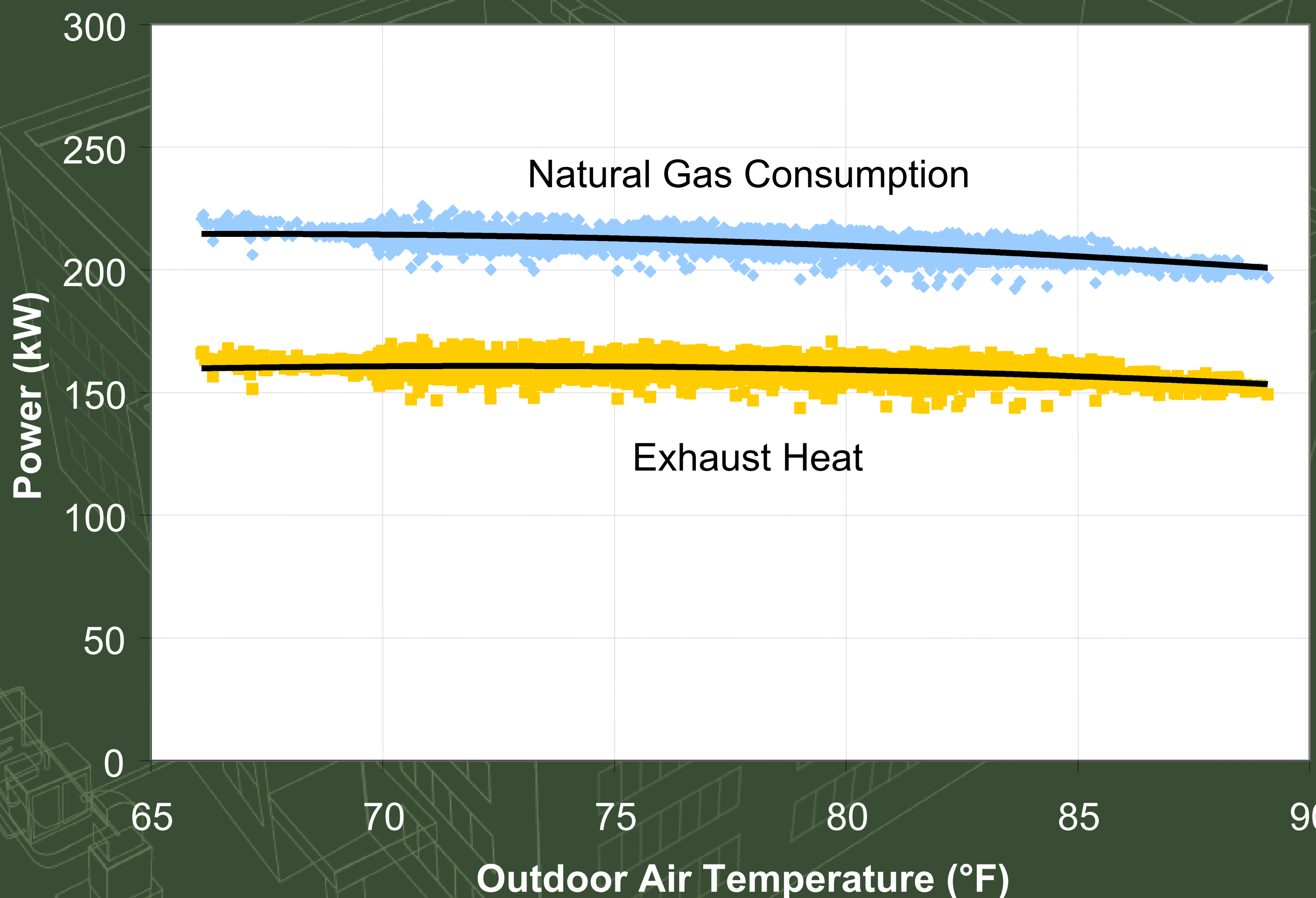
Microturbine Performance Comparison



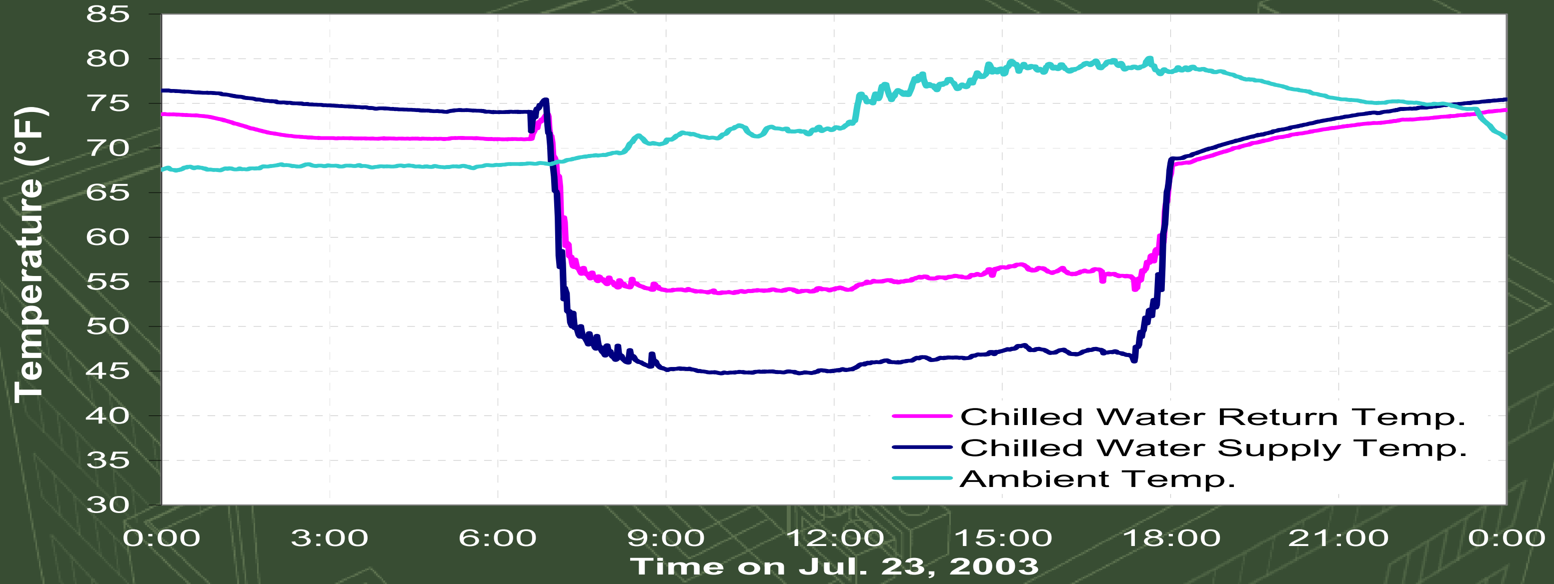
Microturbine Performance Efficiency

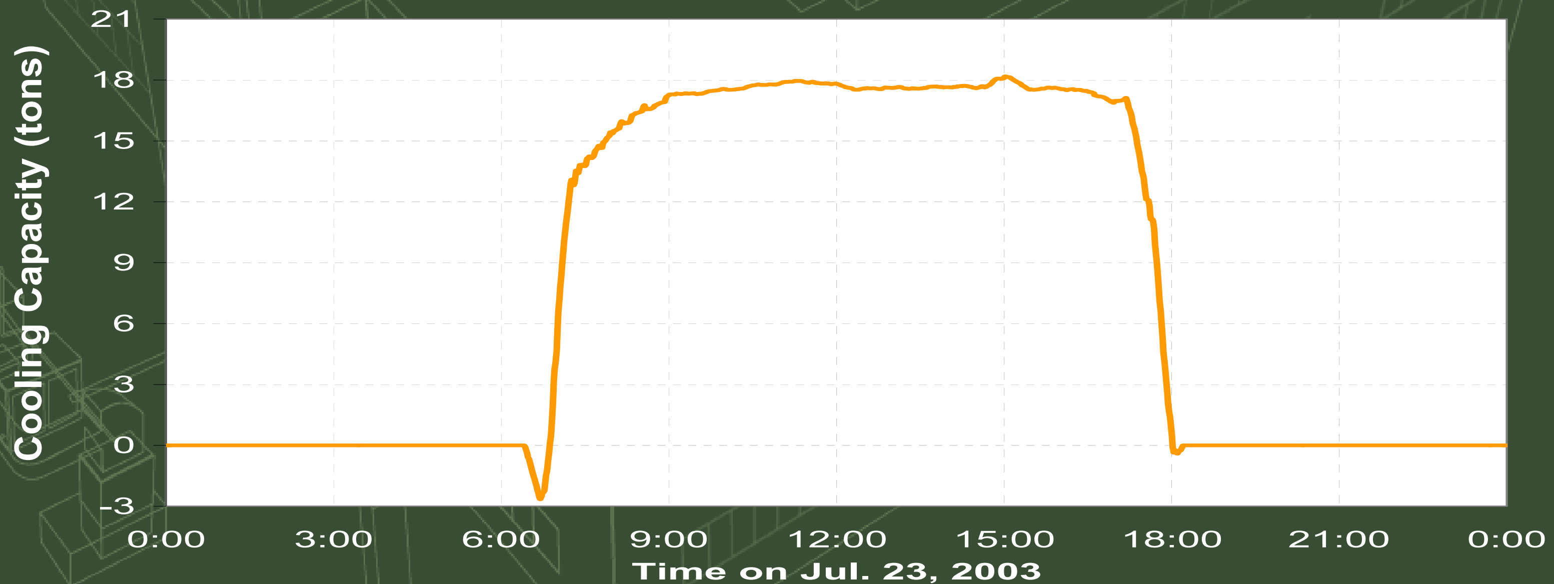


Microturbine Waste Heat

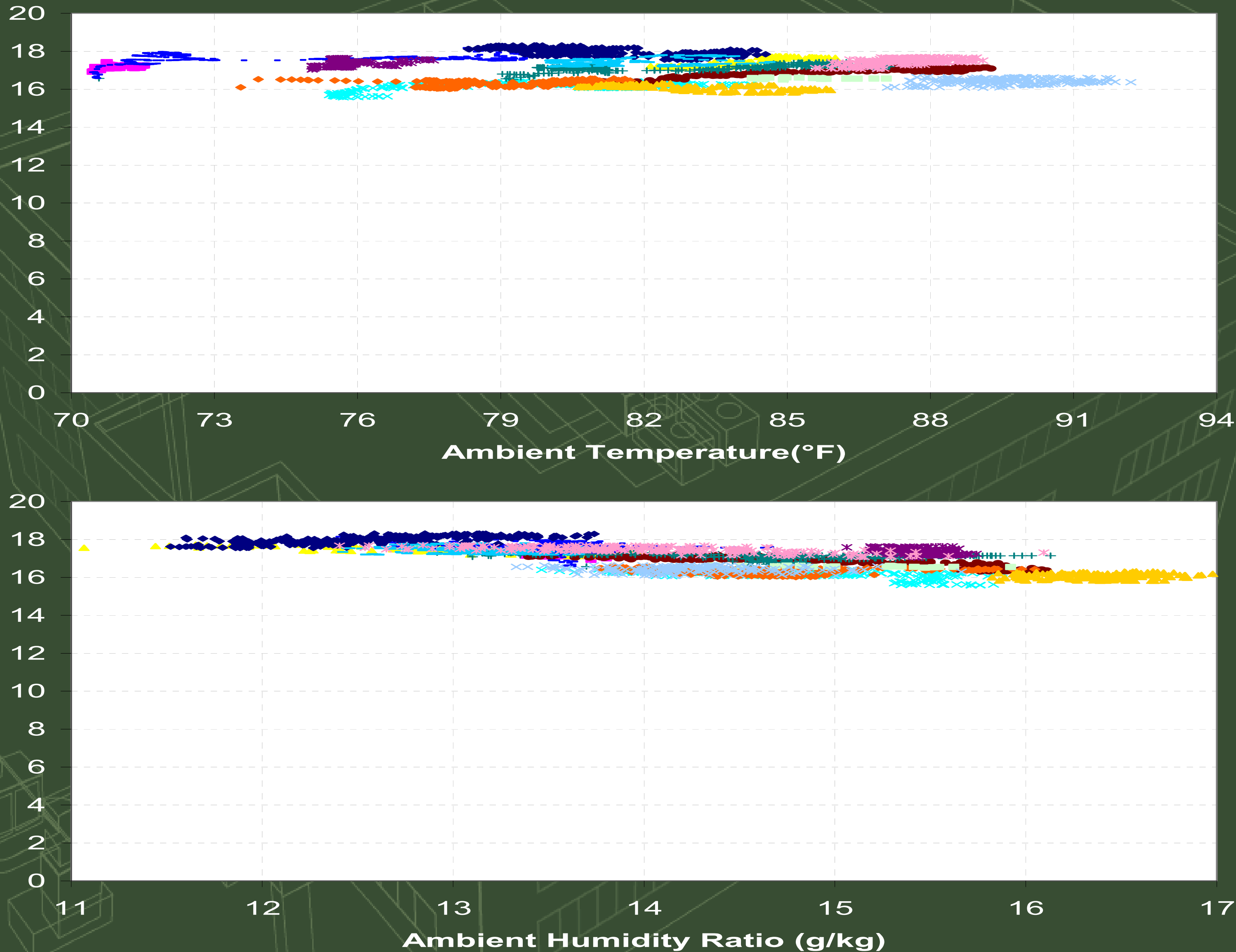


Chilled Water Temp. & Cooling Capacity

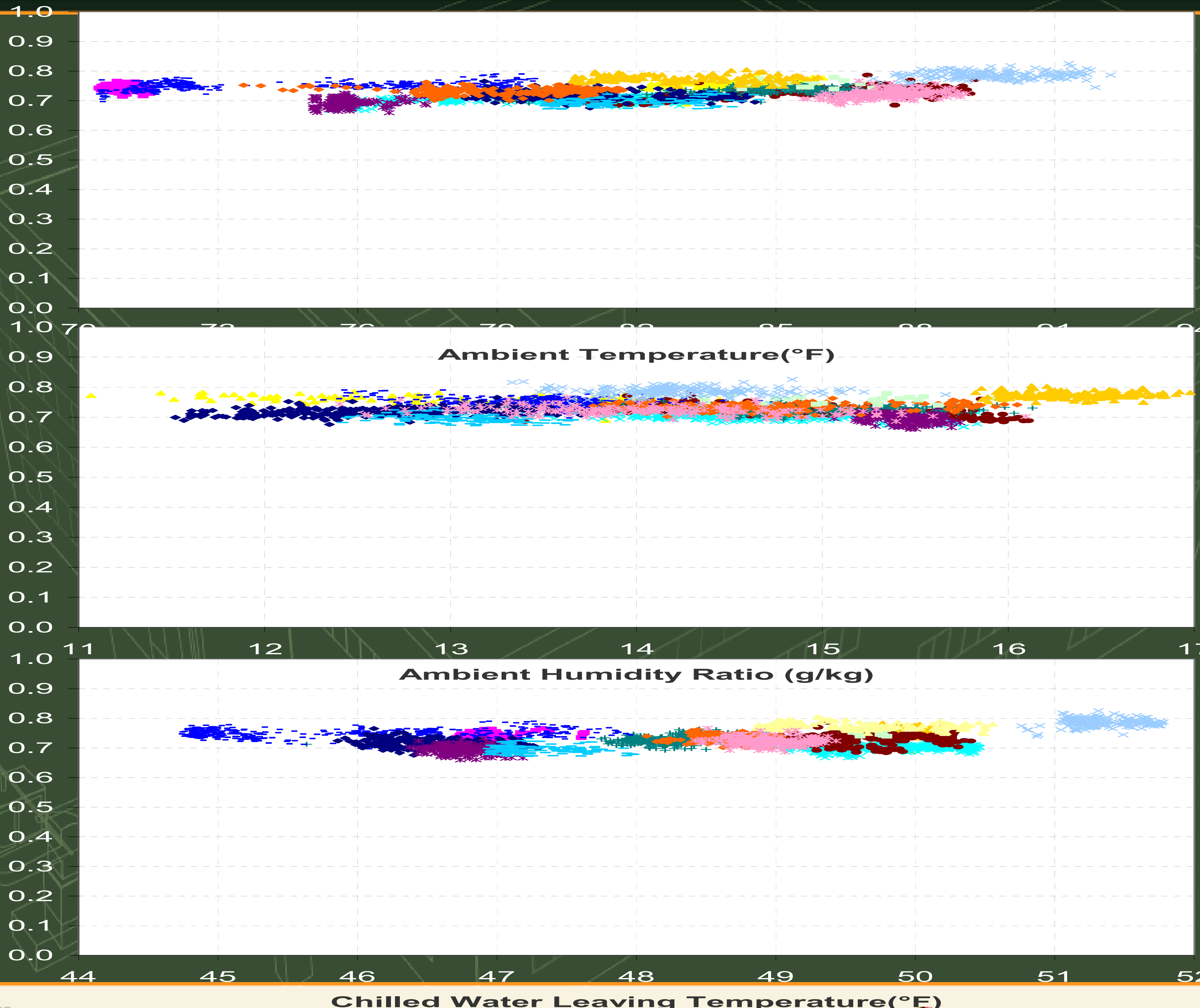




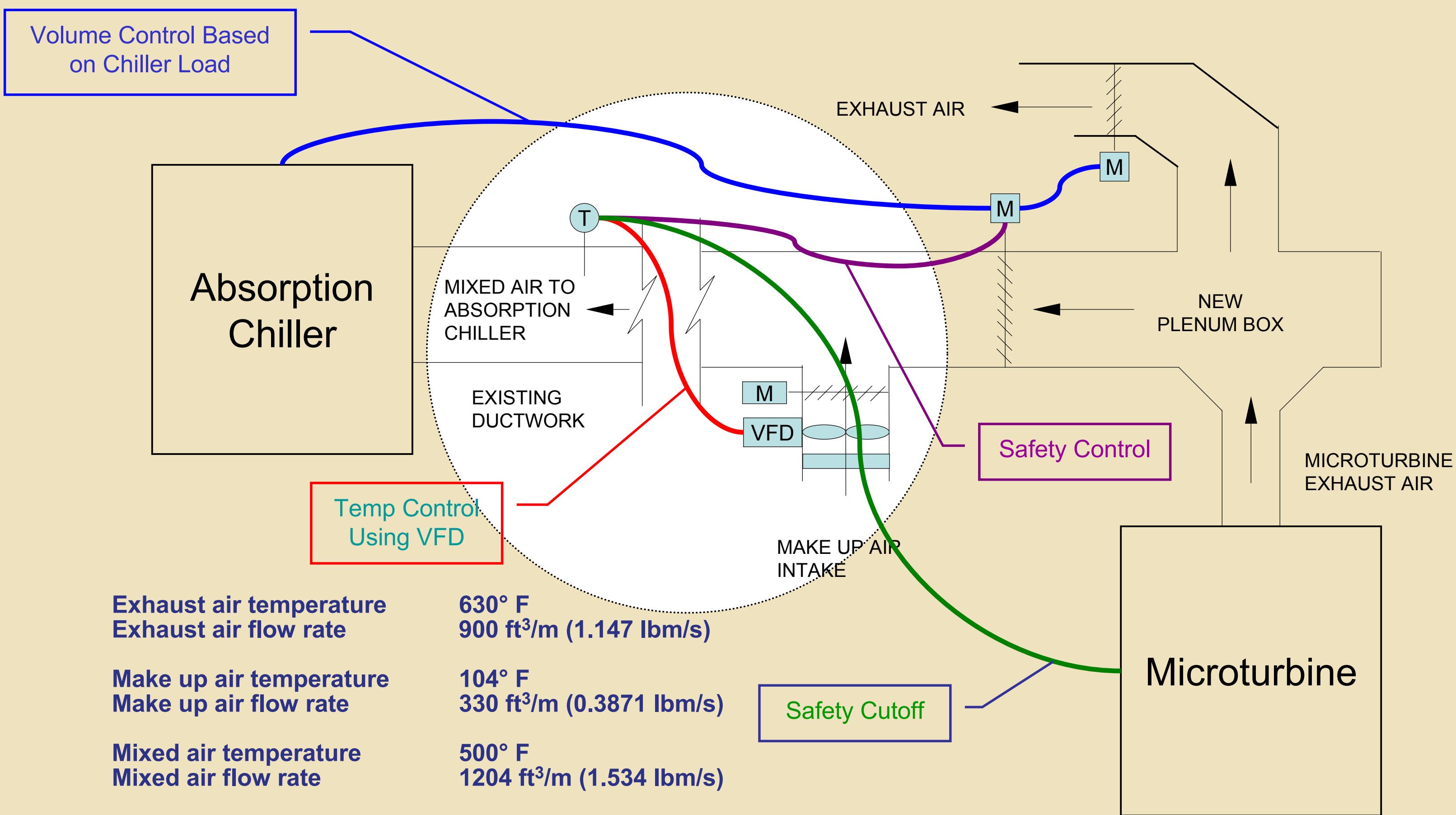
Absorption Chiller Cooling Capacity (tons)



Absorption Chiller COP

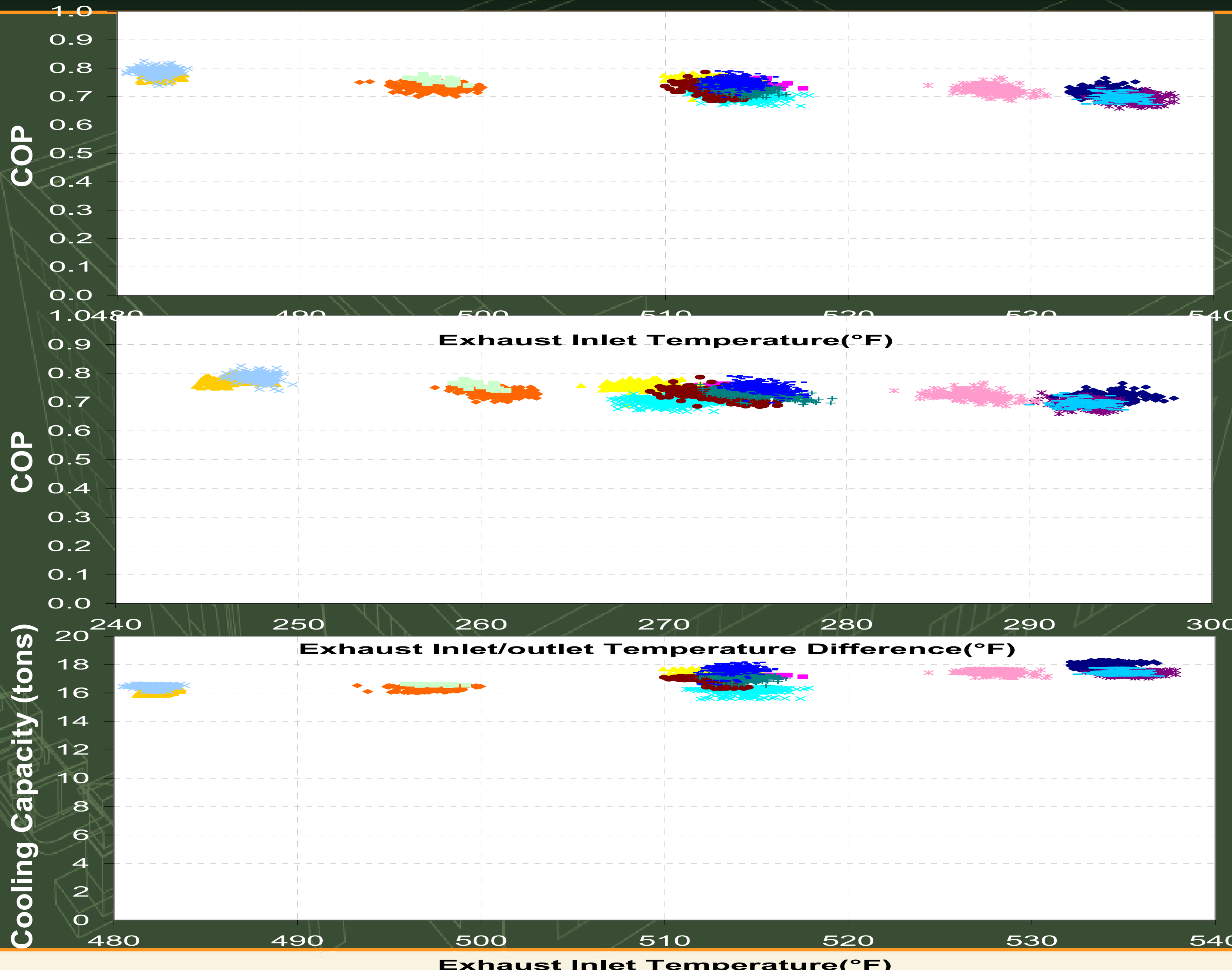


Exhaust Temperature Control



Exhaust air temperature	**630° F**
Exhaust air flow rate	**900 ft^3/m (1.147 lbm/s)**
Make up air temperature	**104° F**
Make up air flow rate	**330 ft^3/m (0.3871 lbm/s)**
Mixed air temperature	**500° F**
Mixed air flow rate	**1204 ft^3/m (1.534 lbm/s)**
Make up air fan	**330 ft^3/m, 5” w.c.**
Insulation	**2”**

Chiller Performance vs. Exhaust Inlet Temp.

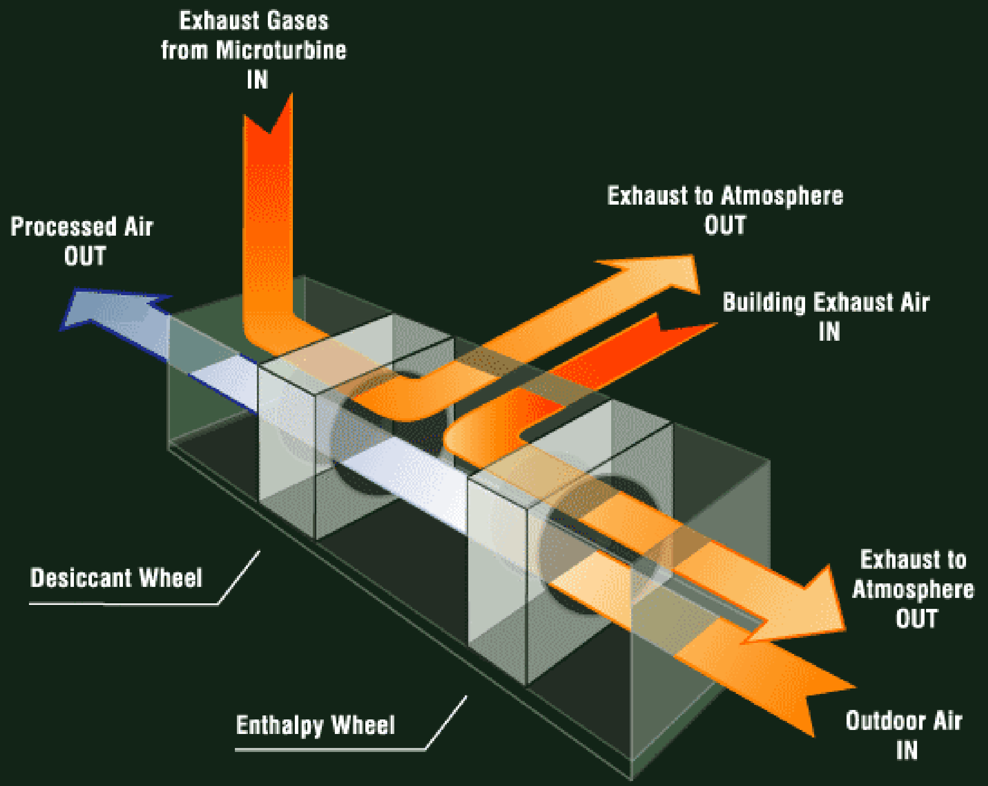


Absorption Chiller Performance Summary

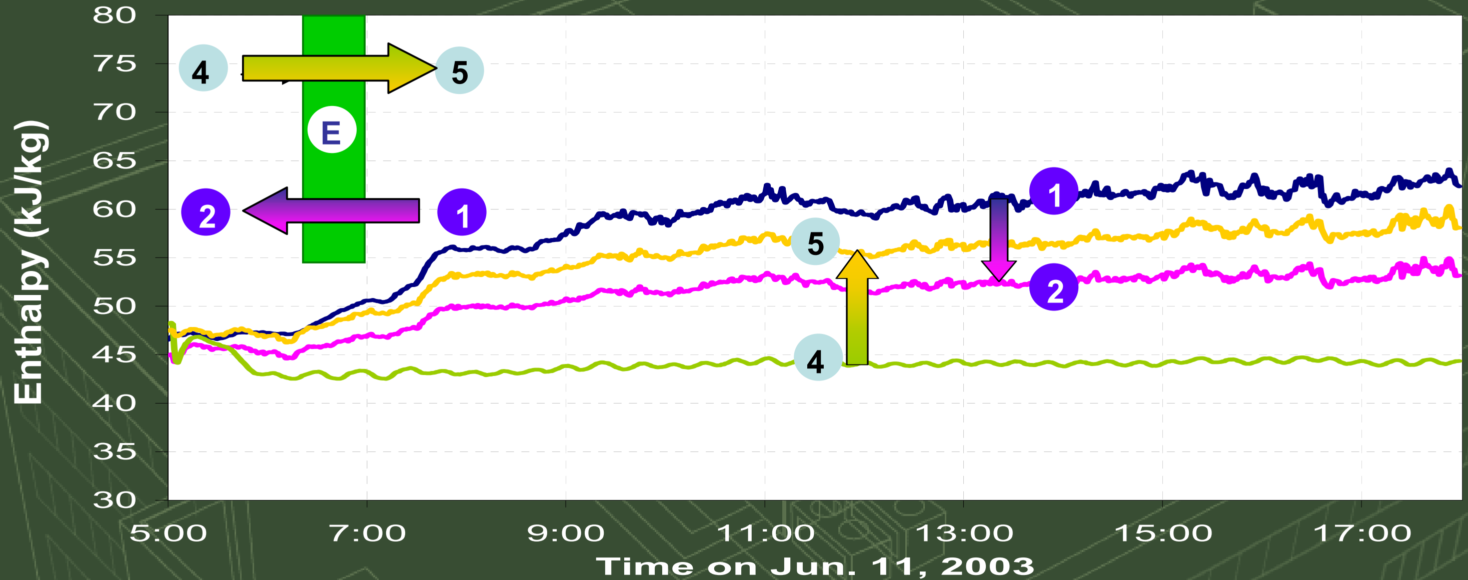
- COP is fairly constant regardless of the combined effect of weather, exhaust inlet temp. and chilled water supply temp.
  - COP thermal = 0.70
- Mean chilled water supply temperature = 48°F
- Mean chilled water return temperature = 57°F
- Mean chilled water temp. difference = 9°F
- Mean chilled water flow rate = 47 gpm
- Mean Cooling Capacity ~ 18 tons.

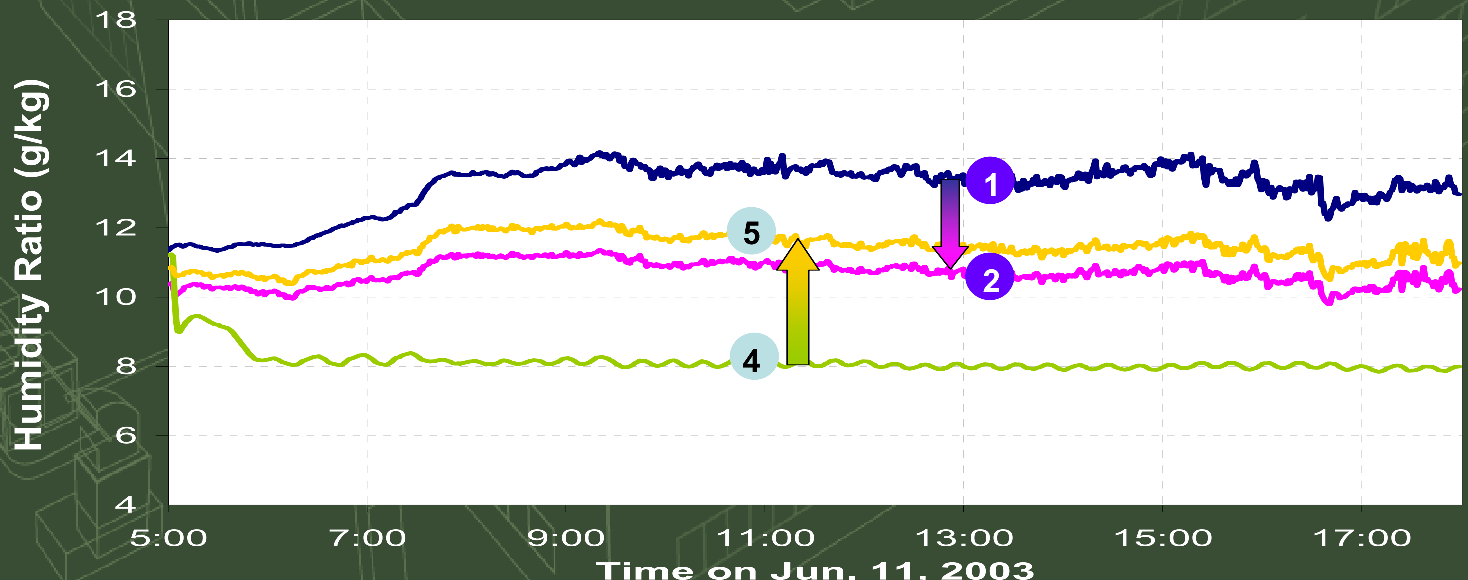
Solid Desiccant

CHP System 2

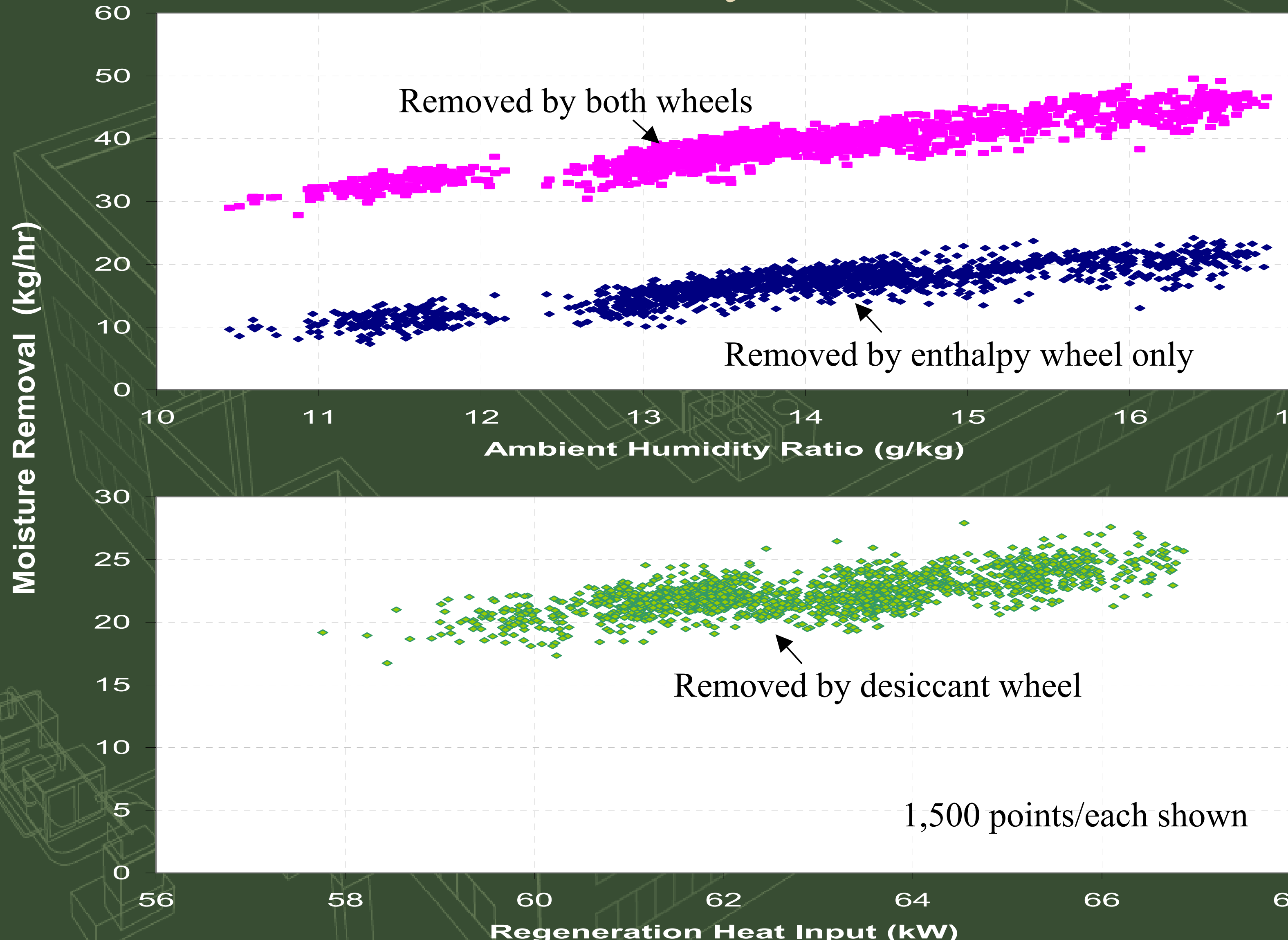


- Testing for performance difference between components – enthalpy wheel change out

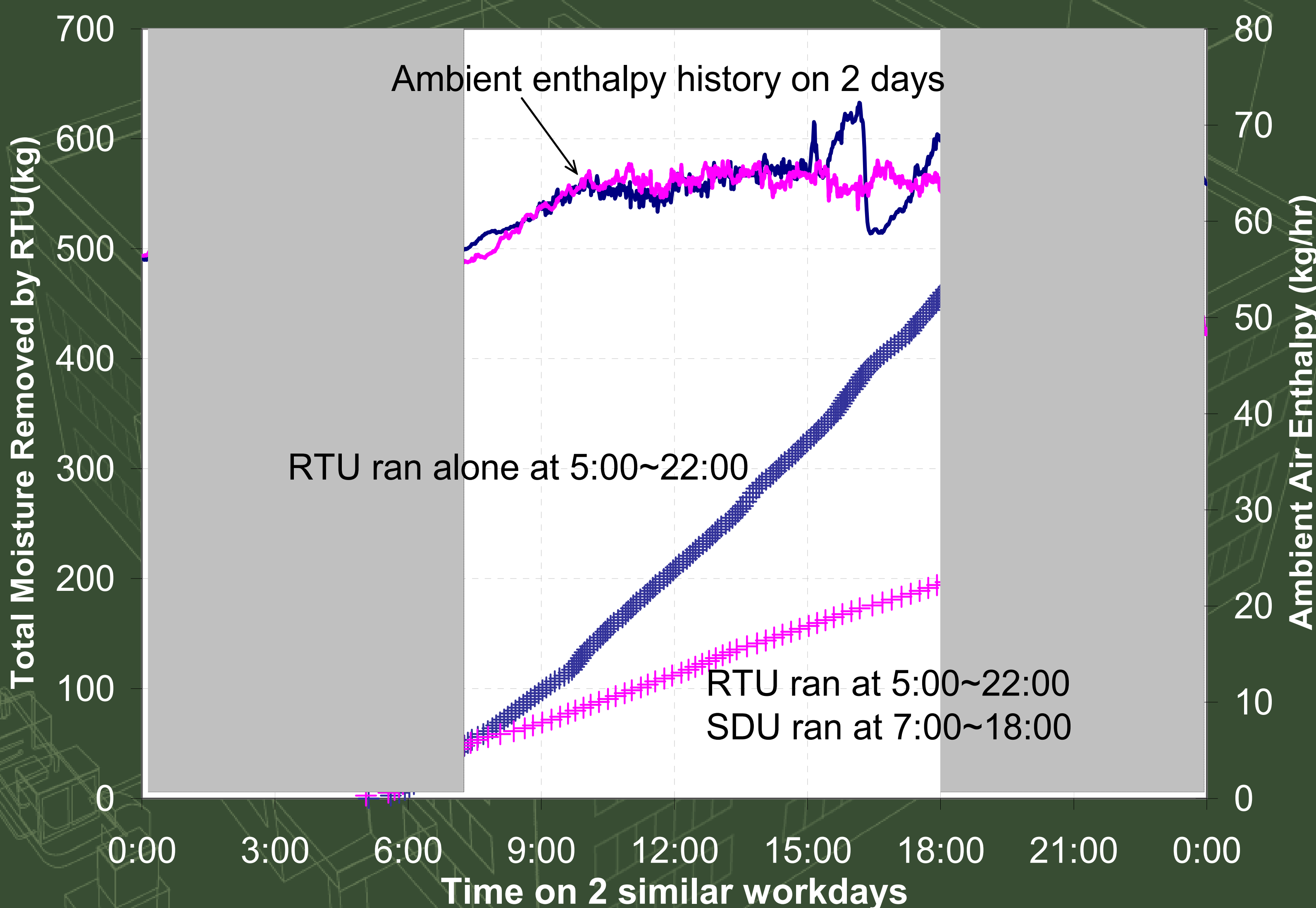

Enthalpy (kJ/kg)
80
75
70
65
60
55
50
45
40
35
30
5:00
7:00
9:00
11:00
13:00
15:00
17:00
Time on Jun. 11, 2003
4
5
E
2
1
5
4
1
2


Humidity Ratio (g/kg)
18
16
14
12
10
8
6
4
5:00
7:00
9:00
11:00
13:00
15:00
17:00
Time on Jun. 11, 2003
1
5
2
4

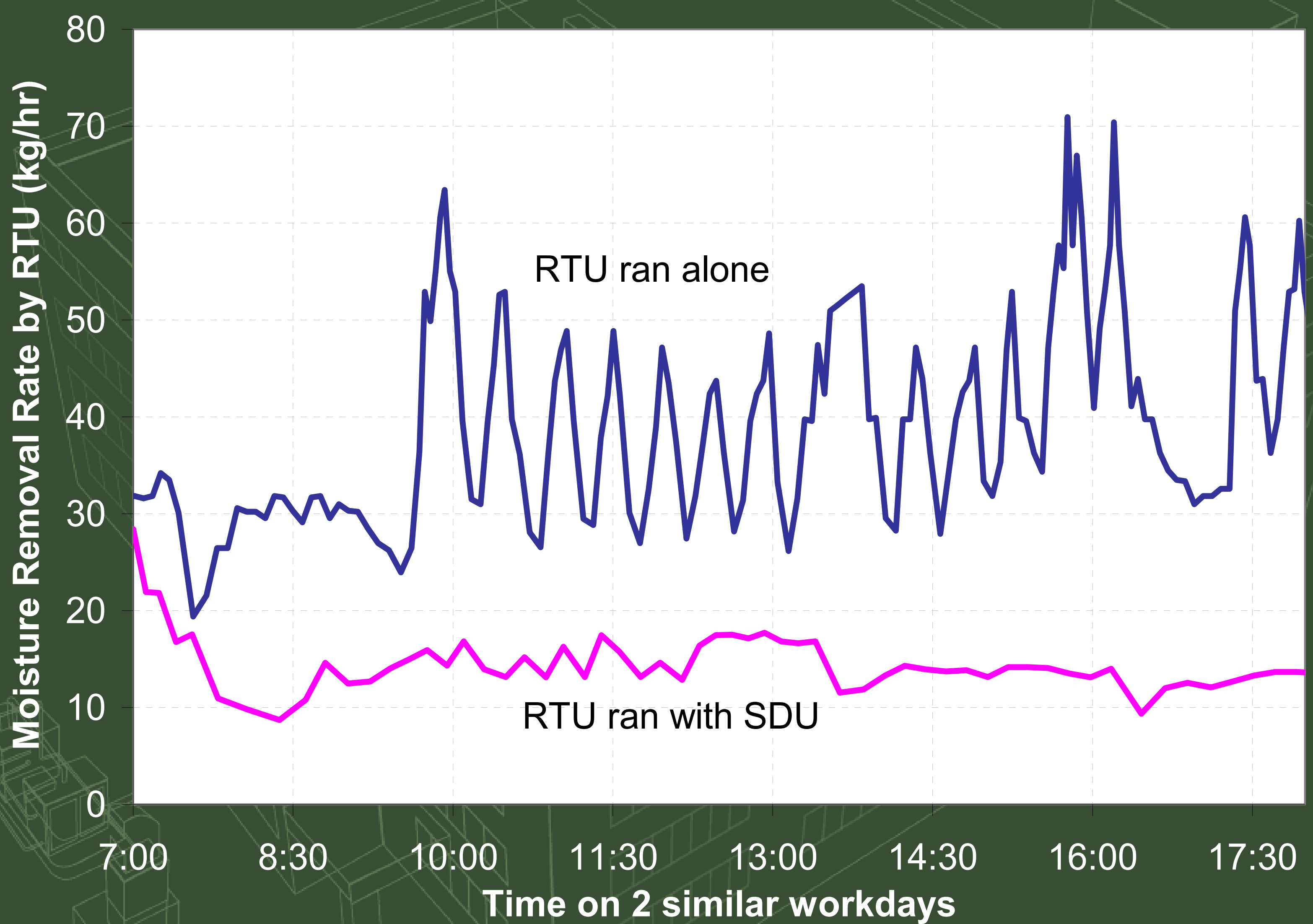
Solid Desiccant Unit Moisture Removal Ability



Comparison of Moisture Removal by RTU



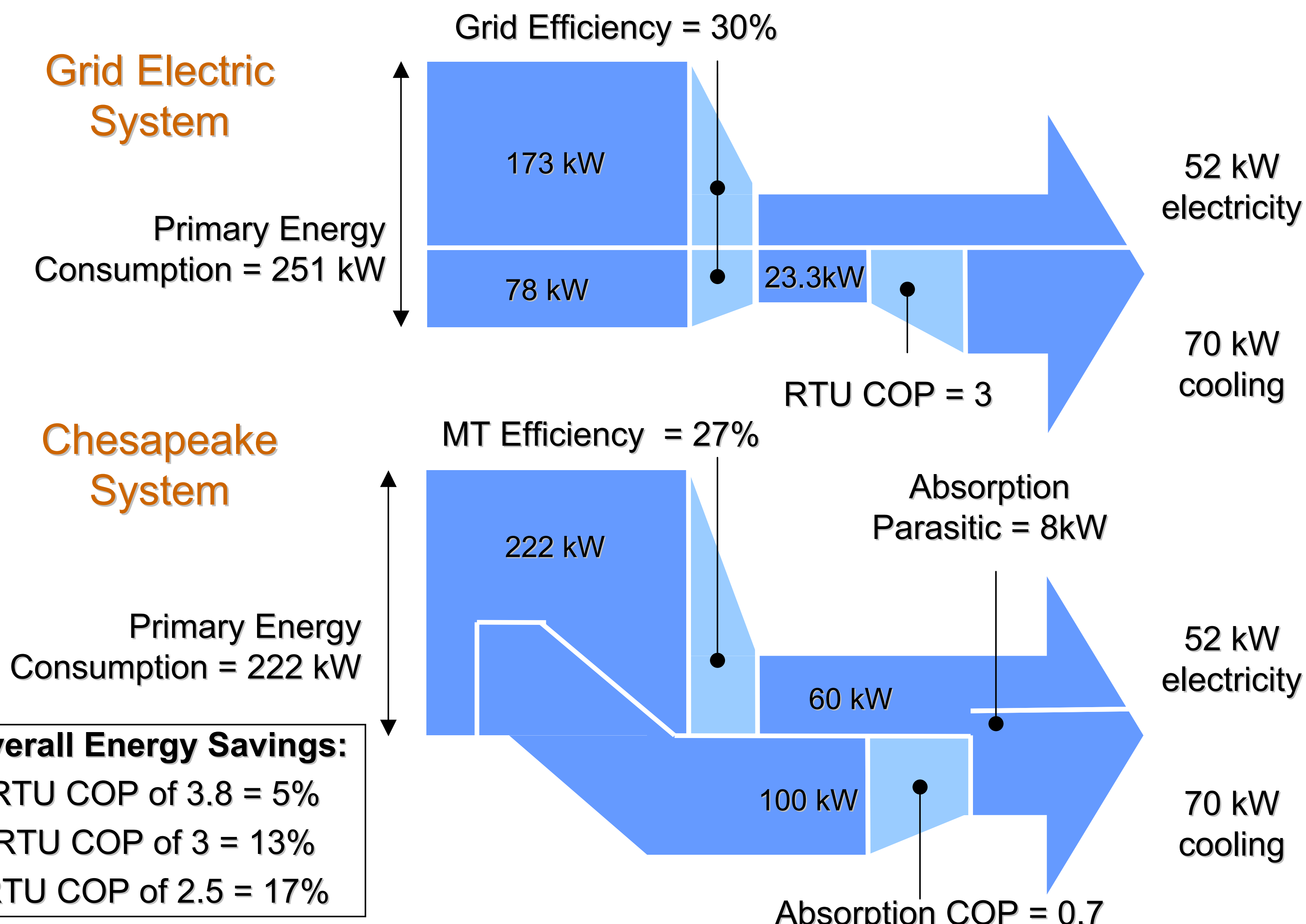
Moisture Removal Rate by RTU



CHP System 2 Energy Analysis

- Nominal output of CHP System 2:
  - 60kW power, 18 tons cooling, 3000CFM dry air
- Efficiency
  - MT 23%~27%
- Effectiveness of Enthalpy wheel
  - 0.75 for Original Wheel, 0.84 for New Wheel
- Desiccant wheel
  - COP latent 0.55
- COP
  - Absorption chiller: COP thermal 0.70
  - RTU COP 2.2~4.8

CHP System 2 Energy Analysis (Cont.)



Overall Energy Savings:

RTU COP of 3.8 = 5%

RTU COP of 3 = 13%

RTU COP of 2.5 = 17%

CHP Know-How/Accomplishments

- CHP integrates dissimilar equipment
- Components are generally designed to do one job well
  - MT produce power
  - Desiccants dry air
  - Absorption chillers produce chilled water
- Many additional benefits are obtainable when design is aimed at system level from start
- We want an INTEGRATED SYSTEM that is clean, reliable, efficient and cost effective

CHP Know-How/Accomplishments

- Exhaust Gas Isolation
  - Protect downstream components from upstream heat production
  - Microturbine Exhaust Dampers – maximum leakage for dampers is 1%

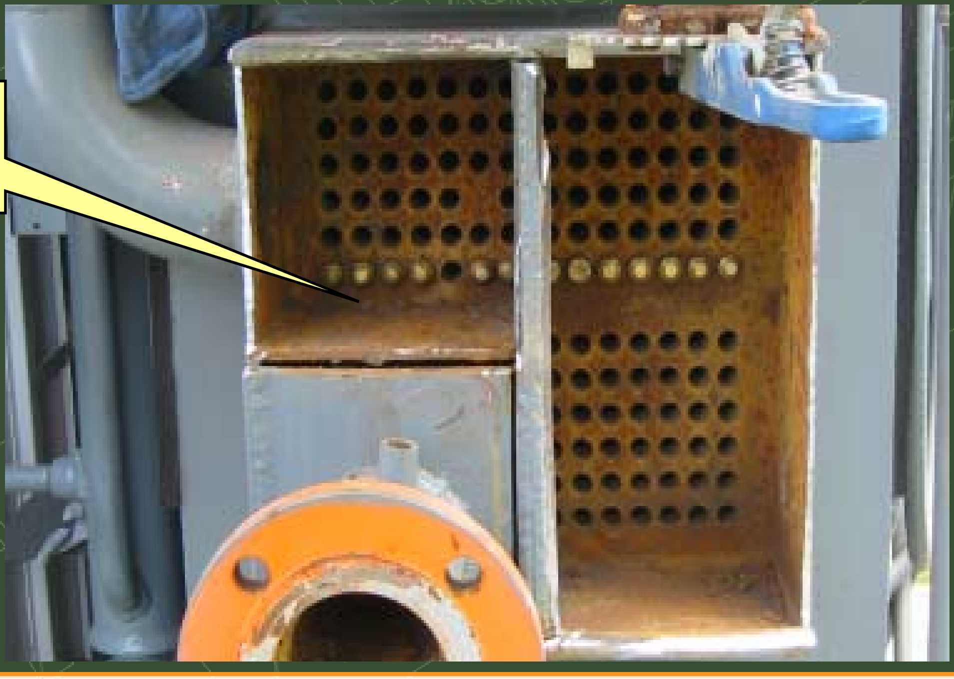
  - Currently adopted by Capstone, UTC Power, Bowman, Broad, GTI, SoCal Gas

CHP Know-How/Accomplishments

- Thermal Management
  - Modular damper manifold allowed for heat buildup in microturbine cabinet causing performance problems
  - Identification of this integration problem led to a redesigned manifold

- Ambient Protection
  - CHP systems are generally located outdoors, but absorption chillers traditionally are not. The cold winter led to condenser tube damage which is currently being assessed to develop necessary design changes.

Tubes Ruptured or damaged due to water freezing



- TAT Integration

Conventional Field Integration

Newly Developed Packaged TAT

Other Experience

- Parameter compatibility
  - Exhaust temperatures vs. waste heat temp. requirements
- Standardization
  - Metric bolts, English nuts, specialist wiring harness tools, star-shaped sockets
  - Transformers, Fuses (5,12,24,120,230,277,480V AC/DC)
- Reduce duplication
  - Sensors
  - Enclosures
  - User Interfaces
  - Controllers and software drivers
- Maintenance Contracts, Manuals

Technology Transfer

- 200 Visitors to date in 2003 in 30 separate groups from conferences, governments, manufacturers, end users and students
  - David Garman, Assistant Secretary of Energy
  - International Congress of Refrigeration
  - Micro CHP Conference
  - Gas Cooling Workshop
- Trigen sponsors 8 undergraduate students and 2 graduate students to study CHP
- 1 Ph.D and 3 Master students graduated.

David Garman visited UMD on May 9, 2003

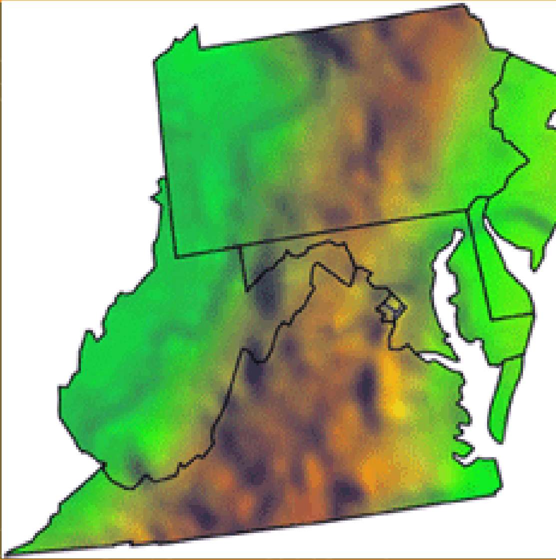
Technology Transfer

- CHP courses
  - One annual undergraduate course
  - One biannual graduate course
- Presenting results and experience at
  - Semiannual consortium meetings
  - Attended/Contributed to 10 Conferences in 2003
  - Presented Workshop on CHP at International Congress of Refrigeration
- 4 papers published in 2003.

Semiannual consortium meetings

Mid-Atlantic CHP Application Center

- Based at University of Maryland
- Goal: Increase CHP Capacity in the Region
- How do we get there?
  - State baseline assessments
  - Partnership building (federal, local, private organizations and manufacturers, ESCOs and utilities)
  - "How to CHP" guidebook production
  - Promote sensible regulations
  - Outreach through website, brochures and conferences
  - Organize workshops



The 7 states covered are NJ,PA, DE, MD, VA, WV and DC

MIDATLANTIC CHP APPLICATION CENTER

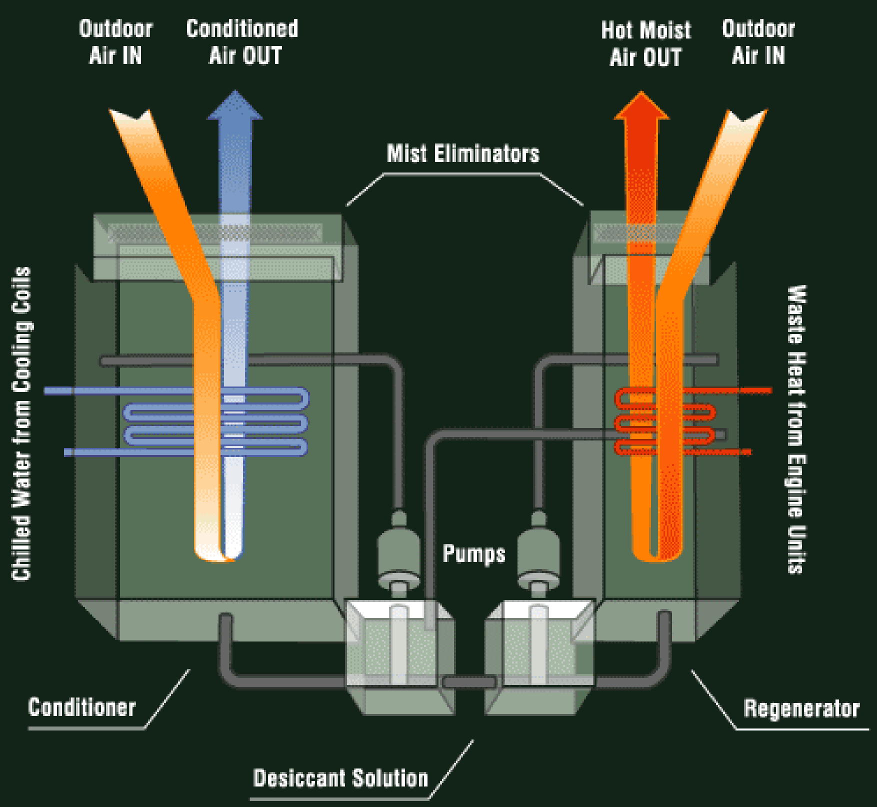
CHP Activities

- Trigen CHP optimization
  - 27MW CHP plant on campus
  - Modeled and optimized in Thermoflex software
- MD IOF Energy Evaluations
  - Grant to visit industrial facilities in MD
  - Development of related research projects

Future Work

Liquid Desiccant

CHP System 1



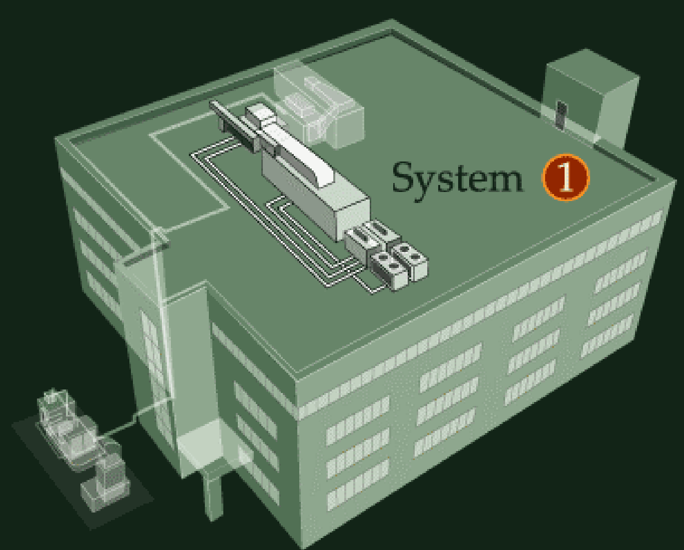
- New engine generator, integrated with liquid desiccant unit
- New microturbine & compact absorption chiller
- Transient modeling
- Heat pipe after desiccant wheel
- Ph.D dissertations
  - air-cooled absorption chiller
  - engine liquid desiccant system integration and performance optimization

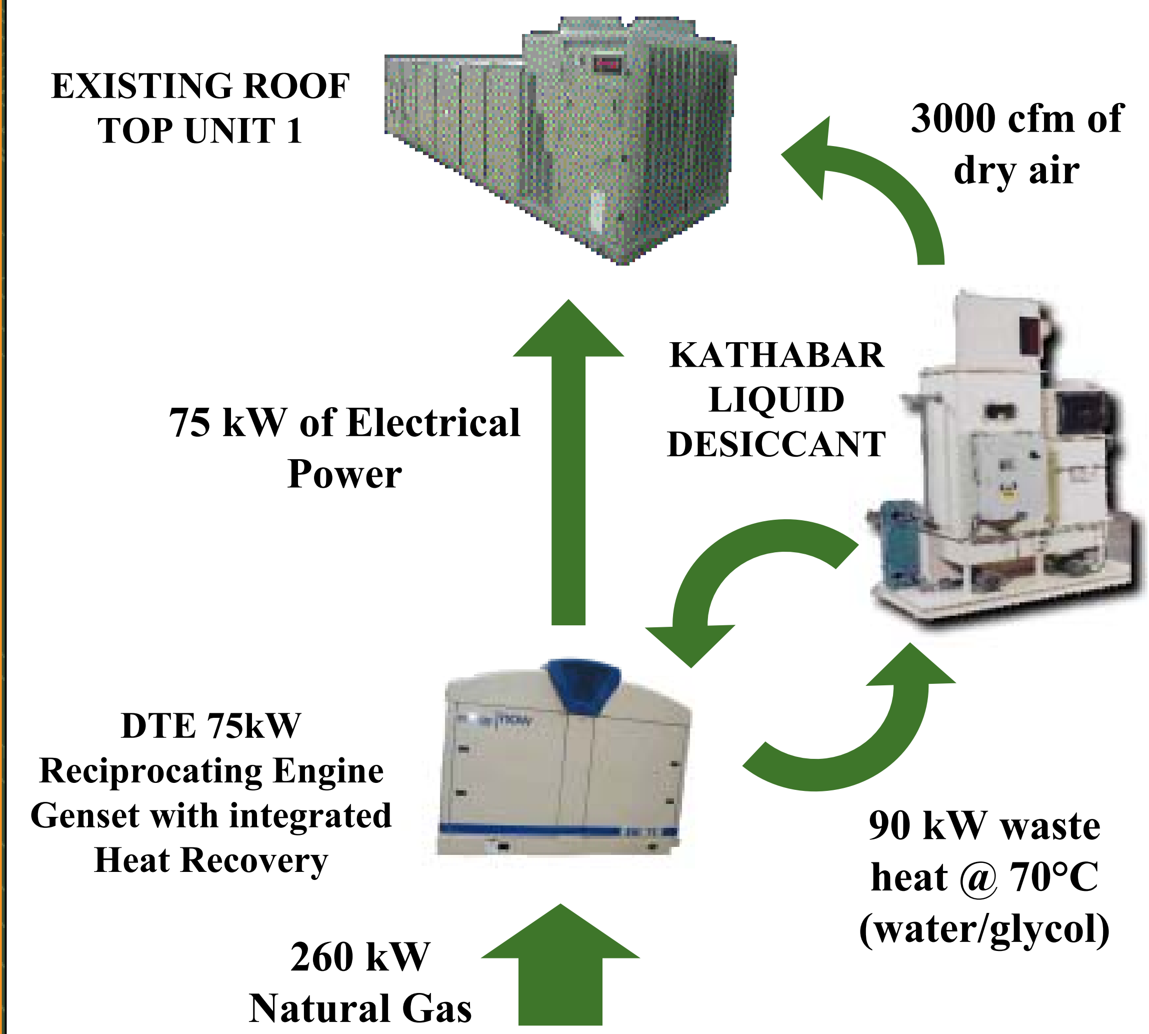
Future Work

- New Genset to replace Engine Driven Air Conditioning Units
- DTE Energy and iPower pre-production model of 75kW reciprocating natural gas engine
- Packaged Heat Recovery – both engine jacket water and exhaust gases
- Provides hot water to regenerate liquid desiccant for CHP System 1

The new DTE 75kW packaged CHP generator

CHP System 1 2004





Summary

- System 2 delivers stable and reliable data
- System 1 in the process of being changed
- Large amount of calibrated, quality field data collected and analyzed
- Fuel flexibility is demonstrated. Micro turbine runs on propane without problem.

Test facility at UMD